Coir Geotextile Roll and Wetland Plants for Streambank Erosion Control

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Complexity	Environmental Value	Cost
Low / Moderate / High	Low / Moderate / High	Low / Moderate / High

OVERVIEW

The coir geotextile roll (CGR) is a sausage-like roll of nonwoven fibers made from coconut husks bound within a polyethylene or coir woven mesh rope (Figure 1). Mr. Lothar Bestmann of BESTMANN GMBH Ingenierbiologie (bioengineering), Wedel, Germany, invented the CGR, referring to it as a *"vegetations-faschine."* The CGR incorporates wetland plants (usually as rooted sprigs or cuttings) whose roots become interlocked with the CGR fibers. The CGR with its plants is used along the face of an eroded streambank and acts principally to armor the bank, though it can also be configured to act as a current deflector. The CGR has the potential to accumulate sediment and, together with the plants, develop a strong network of interlocking roots and plant stems (Figure 2).

Figure 1. CGR after installation along a German stream (photo courtesy of Bestmann GmbH, Wedel, Germany)

The CGR concomitantly benefits fisheries habitat by providing both food and cover due to its proximity to the edge of the stream. When rocks are used at the base of the CGR, the rocks and CGR act together to produce substrates suited for an array of aquatic
organisms. Some of these organisms adapt to living on and within the rocks,

Figure 2. CGR on German stream 1 year after installation (photo courtesy of Bestmann GmbH, Wedel, Germany)

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and some attach themselves to the plants, which they may also use for food.

The CGR can improve water quality and aesthetics. Plants within the CGR, especially emergent aquatic plants, such as bulrush (*Scirpus spp.*) and sedges (*Carex spp.*), will assimilate contaminants within the water column, though the total mass uptake may be small. The CGR can also improve non-point pollution control by intercepting sediment and associated pollutants coming into the stream from overbank areas.

Plants within the CGR can be somewhat tailored to provide color, texture, and other attributes that add a pleasant, landscaped appearance. Such plants include blueflag (*Iris versicolor*, a wetland wild iris with a blue flower), pickerelweed (*Pontedaria cordata*), monkey flower (*Mimulus ringens*), and cardinal flower (*Lobelia cardinalis*).

PLANNING

The first step in the planning process is to ascertain whether a CGR is an appropriate tool to meet project objectives and constraints related to stability and habitat. Team members conducting this assessment should include hydraulic engineers, ecologists, biologists, geologists, landscape architects, and others that have an understanding of stream restoration, fluvial geomorphology, and vegetation and habitat requirements. Questions that must be addressed by the team include the following inter-related items (not exhaustive):

1. Is a CGR the appropriate tool given the magnitude of the erosion problem, e.g. its geomorphic and morphological characteristics?
2. Will the hydrology of the stream accommodate a CGR?
3. Are stream velocities and shear stresses permissible?
4. Are there wetland plants in a reference reach or nearby similar system that can be used as a template (and perhaps material source) for planting the CGR?
5. Will site conditions during construction permit installation?
6. Have consequences of failure been considered and what are they, e.g., what happens if the CGR becomes dislodged and moves downstream?
7. Are the costs acceptable?

Costs for CGR projects are comparable to those for other bank stabilization techniques. The rolls average about \$7.00/ft for 12-in. rolls, \$9.00/ft for 16-in. rolls and \$12.00/ft for 20-in. rolls (all costs are in 1998 dollars). CGRs may be ordered in custom diameters for a higher price. Stakes, anchors, cable, fasteners, stone, backfill, and vegetation plugs add to material costs but vary with design. Because heavy equipment is not required and installation is relatively simple, installation costs are usually minor. Costs for CGR projects with which the authors are familiar range from \$12.00 to \$36.00/lin. ft, with an average cost of about \$24.00/lin. ft.

SITE CONSIDERATIONS

A site suited to a CGR requires a hydrological regime that 1) keeps the invert of the roll wet during most of the growing season, and 2) sustains flows sufficient to keep wetland plants growing well, but not so large or long in duration as to exceed the plants' flood tolerance. Given these requirements, streams best-suited to CGRs are perennial, small to moderate in size, and have a relatively consistent water surface elevation associated with an extended baseflow.

The second-most-important factor in site selection is choosing a site that is not subject to massive amounts of sediment movement that could smother plants within the roll. CGRs have been effectively used, however, to trap soils from upper bank failures and establish conditions for subsequent colonization or planting. When CGRs are used, planting should not be attempted until the upper bank has stabilized.

Other important considerations in site selection are: shade conditions, type of substrate in which they will be placed; and their relationship to the channel thalweg. Most wetland plants that are suitable for planting within a CGR are shade intolerant or at least require some partial sunlight. Therefore, the CGR, as a general rule, should be placed where some sunlight exists. There are exceptions where one can rely on shade-tolerant plants, such as Baltic rush (*Juncus balticus)* or some species of burreed (*Sparganium spp.*). Local USDA Natural Resource Conservation Service offices should be consulted for other local shade-tolerant plants for the area of interest.

Substrate conditions are also important in site selection because the CGR must be securely anchored. If the substrate is noncohesive material, such as sand or silt, anchoring may be problematic because of the lack of friction to hold the anchors in place. Conversely, a substrate laden with interspersed rock or having a rock layer underneath the surface, can require special equipment or materials to achieve anchor penetration.

The CGR should also generally not be placed immediately adjacent to the thalweg unless it is bolstered with stone to protect from scour and undercutting.

DESIGN

The primary design considerations for use of a CGR are as follows:

1. Elevation along the bank with respect to the hydrology of the stream.
2. Sustained velocity and shear-stress thresholds that the CGR must withstand.
3. Toe and flank protection.

Rock toe armor guards against undercutting of the treatment and flank hardening guards against currents working their way behind the treatment and causing it to fail from flanking.

Primary Design Considerations

Elevation of the CGR must be suited to the vegetation for which it provides substrate. In general, the CGR must be at an elevation that permits absorption of water to prevent desiccation of the planted vegetation. But it should not be placed so low as to inundate the vegetation for a period beyond its flood tolerance (Figure 3). If stacked rolls are used, they must be in a position to be wetted quite often or to absorb ground-water percolating from the bank. When willow whips or other woody plants are used between stacked CGRs as brush layers with their basal ends inserted well into a moist zone within the bank, there is no requirement for periodic wetting. In these cases, CGRs are intended primarily to provide temporary sediment and erosion control.

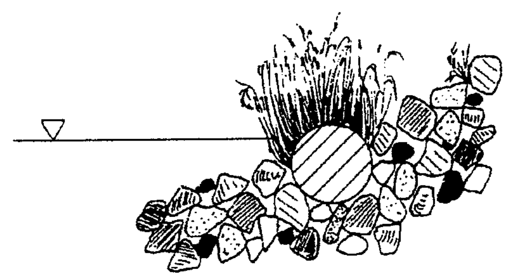

Figure 3. CGR shown at an appropriate elevation to sustain emergent plant growth (from Bestmann GmbH, Wedel, Germany)

Only limited data have been collected for shear or velocity tolerances of the CGR. Available data come largely from empirical information or from vendors' design criteria (Table 1). Designers are urged to exercise caution in considering limiting velocity or shear stress criteria. Failure of CGRs can be attributed to several mechanisms, notably flanking, undercutting and anchor failure.

Table 1. Stress Type and Stress Levels for the CGR

CGR Type	Velocity	Shear
Roll with coir rope mesh (staked only w/o rock bolster)	< 5 ft/sec	0.2-0.8 lb/ft^2
Roll with polypropylene rope mesh (staked only w/o rock bolster)	< 8 ft/sec	0.8-3.0 lb/ft^2
Roll with polypropylene rope mesh (staked w/ rock bolster)	< 12 ft/sec	>3.0 lb/ft^2

Protection to guard against undercutting and flanking the treatment is essential for success. For toe and flank protection, rock bolsters should be designed for velocities and shear stresses exceeding allowable limits for the soils underlying the CGR. Table 2 presents these limits. Angular rock is recommended and should be sized in accordance with U.S. Army Corps of Engineers (1994) specifications depending on anticipated velocities and shear stress.

Flank protection can also be aided by keying the ends of the CGR into the banks at both ends and protecting the flanks with a rock bolster. The ends should be keyed into the bank by inserting at least two linear feet of roll into the bank with rock on the upstream side, which is also keyed into the bank. For banks susceptible to significant erosion, keys or refusals should extend further into the bank.

Table 2. Threshold Conditions

Class name	d_s (in)	ϕ (deg)	τ^*_c	τ_c (lb/sf)	V_c (ft/s)
Boulder					
Very large	>80	42	0.054	37.4	25
Large	>40	42	0.054	18.7	19
Medium	>20	42	0.054	9.3	14
Small	>10	42	0.054	4.7	10
Cobble					
Large	>5	42	0.054	2.3	7
Small	>2.5	41	0.052	1.1	5
Gravel					
Very coarse	>1.25	40	0.050	0.54	3
Coarse	>0.63	38	0.047	0.25	2.5

Other Design Considerations

Other design considerations include the number and diameter of rolls needed to protect a streambank. Also, the length of bank-reach being eroded will determine the number of rolls needed. They normally come in 10- or 20-ft lengths but can be custom tailored to fit certain situations if warranted.

Eroded banks may not always be conducive to CGR installation and may require either reshaping or filling to accommodate one or more CGRs. If fill is required, rock fill is often used to prevent undercutting. Fill will need to be calculated based on cross-sectional area of the bank times the length of reach. Size of rock and appropriate gradation should be determined from U.S. Army Corps of Engineers (1994).

CONSTRUCTION

The primary considerations conceming construction with a CGR are bank preparation, physical handling and placement, and securing the rolls. Securing the rolls includes fastening rolls together, anchoring them, and protecting them from undercutting and flanking as mentioned in the above section. Another consideration is whether to plant them before movement to the site or at the site.

Handling the CGR can be a problem if it is deposited into water before it is ready to be positioned in its final resting place. A roll weighs about 7 to 20 lb/ft when dry, depending on diameter, and it is easily handled by two to four people. When allowed to absorb water, it can become almost seven times as heavy, making it very difficult to maneuver by hand.

The CGR's ends are fastened together by flattening them with a shovel and lacing together the rope mesh encasing the respective rolls. The nylon tie-rope used for lacing is similar in size to that used for Venetian blinds.

Bank preparation may include cutting or filling as mentioned above. If stone is used to prevent undercutting and flanking, special anchoring techniques may be required to secure the roll to the stone. One method is to drive a row of pipes (sized to fit the anchors) into the substrate in a line along an elevation contour slightly above the invert of the roll (Figure 4). Rock is placed around the pipe so that the proper elevation of fill is achieved. The top of the pipe extends to a height equivalent to the radius of the roll. Earth anchors (with wire) that toggle much like a ship's Danforth anchor are dropped through the pipe. A long piece of rebar is used to drive the anchor into the substrate below the end of the pipe. The rebar is removed and the wire is pulled tight to toggle the anchor until it can no longer be moved. The wires are brought together around the CGR, pulled tight, and coupled together by use of either U-clamps and bolts or a Gripple© fastener that works similar to a Chinese finger puzzle and requires no bolts and nuts. Four pairs of anchors are required for each 20-ft-long roll. After the bottom row of CGRs is installed, successive rows of CGRs can be laid on top and secured to the bank with 2- by 2-in. wooden stakes or earth anchors. The rolls are also laced to each other by nylon rope running through the mesh encompassing each roll through the coir or polypropylene rope.

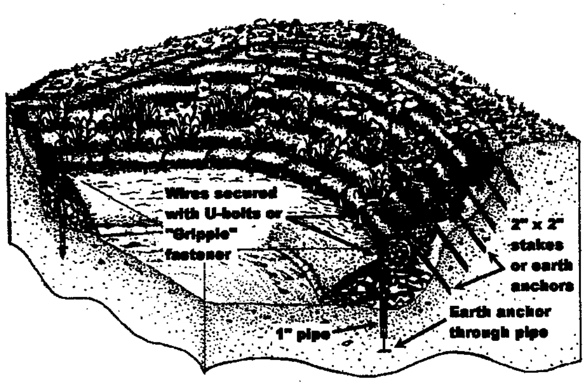

Figure 4. Bank section requiring rock fill showing special anchoring technique (adapted from Bestmann GmbH, Wedel, Germany)

Another alternative for securing the CGR to rock fill consists of using a backhoe with a "stinger" adapted to the boom of the backhoe as shown in Figure 5 (Hoag 1994). The stinger is a solid, pointed, metal rod. The backhoe operator inserts the stinger between the rocks to create a pilot hole. A 3- to 4-in.-diam pole or post (can be a dormant willow post) is inserted into the pilot hole and covered with a metal cap having a wall inside the cap for pushing purposes. Both the cap and the post are pushed by the backhoe with stinger into the pilot hole (Figure 6) to create a post emerging from the ground (Figure 7). The CGR can be fastened to this post either by tie-wire and fence-post staples or some other material.

Rolls not placed on stone can be secured to the bed and bank directly by using 2- by 2-in. wooden stakes, posts, or earth anchors similar to those described above.

The CGR needs to be keyed into the bank or abutted to a hardpoint, preferably a rock refusal that has a rock root back into the bank to prevent flanking.

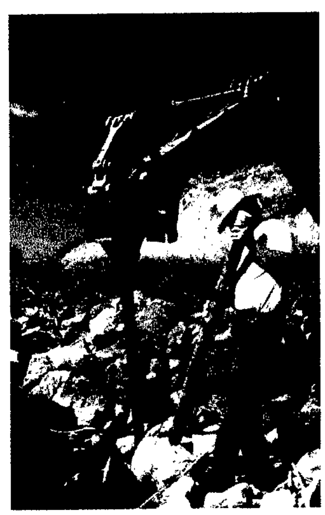

Figure 5. Stinger on backhoe making pilot hole in which to insert a dormant willow post (photo courtesy of Chris Hoag, NRCS)

Figure 6. Stinger inserted into metal cap pushing willow post into rock (photo courtesy of Chris Hoag, NRCS)

Planting a CGR can be accomplished by either pre-growing plants hydroponically in water troughs at the nursery or by planting them in place along the streambank. In either case, one must create a hole in the CGR in which to

Figure 7. Willow post emerging from the ground (photo courtesy of Chris Hoag, NRCS)

place a rooted plant such as a sprig of an emergent aquatic wetland plant, e.g., bulrush, sedge, or rush. The spacing between the holes can vary, but usually ranges between 4 and 6 in. The hole is created by hammering or driving a sharp-pointed bar or stake into the roll. After the hole is made, a 6- to 10-in. rooted sprig is inserted into the hole and the hole is wedged back together. Small-diameter wire can be laced through the CGR fibers to hold the plant more securely in place.

Sometimes, a CGR is planted with rooted cuttings of woody plants such as willow or alder. The planting procedure is the same as for emergent aquatic wetland plants described above if the woody plants are to be inserted into the CGR. At other times, willow and other woody plants that sprout from unrooted cuttings are inserted between stacked rows of CGRs as whips that extend back into the soil bank. The whips are placed in one or more layers for this purpose (Figure 8).

OPERATION AND MAINTENANCE

Operation and maintenance requirements of any bioengineering treatment will vary depending on the stream system and its associated parameters, such as velocity, flood

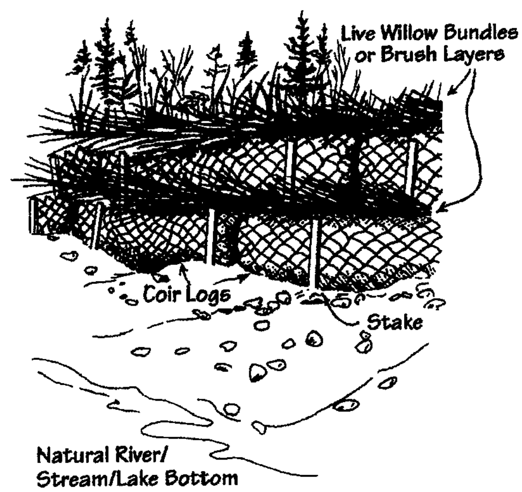

Figure 8. Live willow whips in layers inserted between CGRs

frequency, flood stage, and timing. In any case, one should be prepared, at least early in the project life, to repair the system until plants can become established. Minimally, inspection should occur after each

of the first few floods or at least once a year, preferably after the predominant flood season.

Undercutting and flanking of the treatment and any other substantial scour evidence should be observed. Plants should be examined for adequate survival and growth and absence of disease, insect, or other animal damage (e.g., grazing, digging, and cutting). Successful plants will grow vigorously and spread their roots into both the CGR and the surrounding substrate.

If animal damage is evident, such as plants being removed or eaten by waterfowl, preventative measures, such as use of exclosures, may be required. Such exclosures may only need to be temporary until plants are well-established.

Assuming the CGR remains in place and plants root and become established in the CGR, maintenance becomes much less intensive as time progresses.
Fish and aquatic invertebrate sampling is always recommended both before and after installation to determine habitat improvement effectiveness.

APPLICABILITY AND LIMITATIONS

Techniques described in this technical note are generally applicable where primary objectives for streams include habitat diversity, erosion control, and aesthetics, including a diversity of plants along the streambank. Use of the CGR is limited to streams having fairly constant and consistent base flows. If streams are ephemeral, CGRs will dry out and plants within them will die. If aquatic herbaceous plants are used, streams should not have excessive sediment loads that may completely cover and smother plants.

Caution should be exercised in using a CGR without a rock bolster when stream velocities at the bank exceed critical thresholds for underlying soils.

Trampling and grazing of a CGR, particularly when planted with emergent aquatic plants, can be detrimental. Use may be limited in areas where human traffic is concentrated or where cattle grazing is nonrestricted.

Consequences of failure should be considered if a CGR is flanked and washed downstream. Is failure likely to create hazards that otherwise would not occur (e.g., trapping debris and causing undesired local scour, current deflection, and damming)?

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REFERENCES

Haslam, S. M. (1978). *River plants, the macrophytic vegetation of watercourses.* Cambridge University Press, Cambridge.

Hoag, C. (1994). "The Stinger," TN Plant Materials No. 6, June 1994, USDA Soil Conservation Service, Boise, ID.

U.S. Army Corps of Engineers. (1994). "Hydraulic design of flood control channels," Engineer Manual 1110-2-1601, Change 1, 30 June 1994, Washington, DC.